The Faringdon Sponge-Gravels (England)

Renate Krantz, Tübingen

Translation by Jennifer Felsenberg, Department of Earth Sciences, University of Oxford (18hrs), April 2017

Introduction

Until the introduction of tar, the Lower Greensand Sponge-Gravels of Faringdon were well established and widely used as pavement gravel. This is evident from the "Lithophylacii Britannici Ichnographia", in which fossils "e sabuleto quodam prope Faringoniam" and "e sabuleto Coxalense" were initially described by LHYD (1760).

In the middle of the 19th century, when geology was a popular and specialist leisure activity of upperclass English society, Mantell described the Sponge-Gravels in his popular science books "Medals of Creation" and "Wonders of Geology", and Faringdon was the destination of numerous excursions and trips.

Austen was the first to study the stratigraphy of the Lower Greensand, and especially of the Sponge-Gravels, which, in his opinion, came to be deposited in a water depth of 40 fathoms (= 80 m). He concluded that far transport of the fossils from their origin was impossible.

Sharpe (1854) viewed the individual layers of the Lower Greensand of Faringdon as lenticular bodies, and placed the Sponge-Gravels as their youngest?unit in the Maastrichtian due to misleading faunal comparisons. MEYER (1864) determined the final stratigraphic classification. He divided the Lower Greensand into the following strata:

4. Sand with some chert and ironstone
3. Sandy clays
2. Red Gravel
1. Sponge Gravel (=Yellow Gravels, Melville 1937)

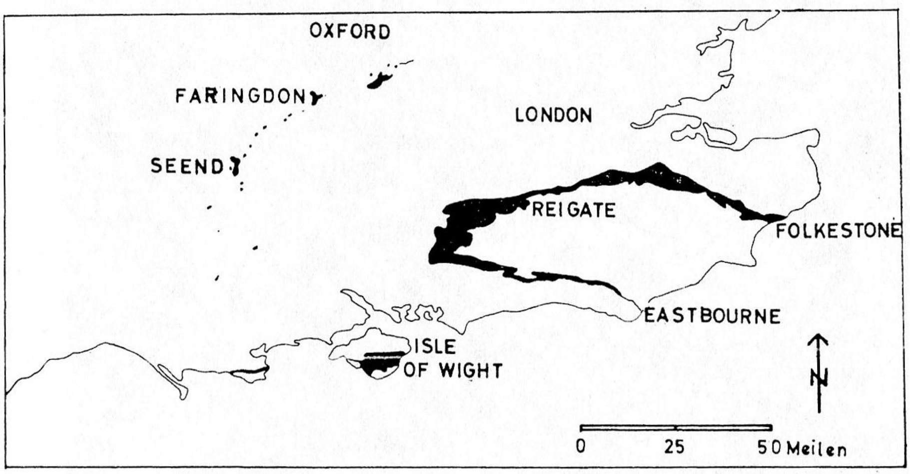

Abb. 1. Ausstriche von Lower Greensand in S-England (nach CASEY 1961).
Fig. 1. Lower Greensand outcrops in S-England (after CASEY 1961).

The individual layers of this sequence are, in his opinion, through-flowing (continuous?) horizons. In 1937 the Lower Greensand of Faringdon was revised by MELVILLE as part of a mapping. He resumed SHARPE'S theory (1854). In an excavated exposure, he saw that the Sponge Gravels laterally wedged out at a sharp erosive boundary against the Sandy clays, concluding that the various occurrences of Sponge-Gravels were originally deposited in non-contemporaneous beds.

In 1970 the area around Faringdon was explored to a greater extent through drilling by the Geological Survey. This showed the Sponge-Gravels to have a wide extent as a basal conglomerate of the Lower Greensand and apparently originally formed a rapidly southwards thinning wedge. In addition, boreholes enabled a reclassification of the Lower Greensand of Faringdon (POOLE & KELK, 1971), Fig. 2.

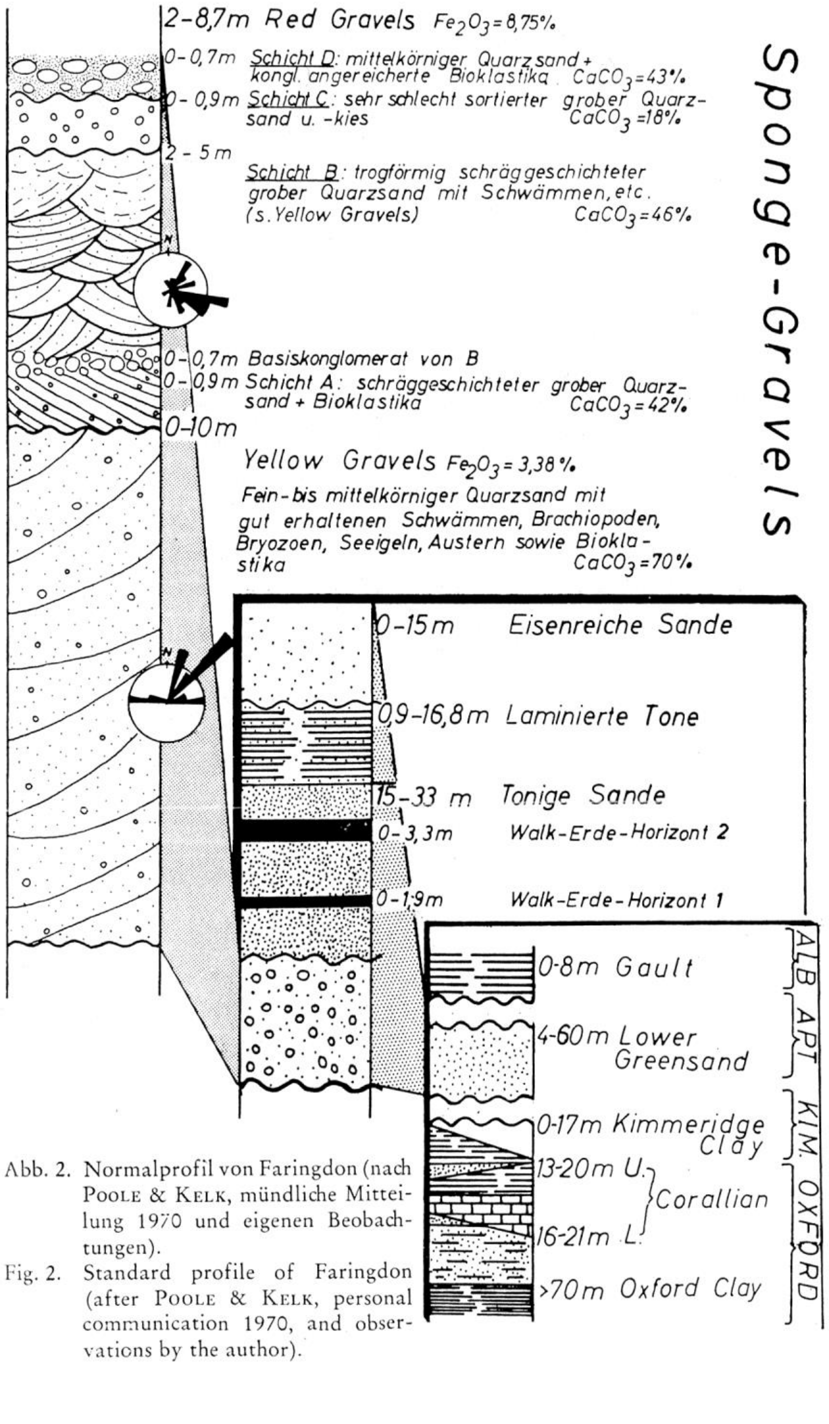

Abb. 2. Normalprofil von Faringdon (nach POOLE & KELK, mündliche Mitteilung 1970 und eigenen Beobachtungen).

Fig. 2. Standard profile of Faringdon (after POOLE & KELK, personal communication 1970, and observations by the author).

The Sponge-Gravels

Distribution and Thickness (Fig. 2; Fig. 3)

Exposures:

1. In Little Coxwell Pit, (MEYER’S Windmill Pit, MEYER 1864)
   About 1 km south of Faringdon, the Yellow Gravels are at least 30 ft thick (MEYER, 1864), and are overlain by 6 ft thick heavily weathered Red Gravels (ARKELL 1947, MELVILLE 1937). Only the top 12 ft of the exposure are still accessible today.

2. Faringdon Pit,
   300 m east of Little Coxwell Pit, where today about 10ft of Red Gravels are exposed, previously extended into the Yellow Gravels. MEYER (1864) describes 6ft of Yellow Gravels overlain by Red Gravels to a thickness of 20ft (Profile: East Pit, MEYER 1864). In ARKELL's time, 14ft of the Yellow Gravels were exposed. ARKELL (1947) also mentions a 1ft thick conglomerate between Red and Yellow Gravels.

3. In Wicklesham Pit,
   A 35ft deep outcrop in the Red Gravels, about 300 m east of Faringdon Pit, this conglomerate is still exposed today, not at the base but in the middle of the Red Gravels and 16ft lower than in Faringdon Pit (ARKELL, 1947).

4. The Sponge-Gravels are only 8ft thick in a nowadays filled-in exposure of Little Coxwell (MELVILLE 1937).

Boreholes:

The drilled deposits are between 20 cm and 7 m thick. They contain pebbles from the Corallian or from calcareous layers of the Kimmeridge clay, a few fossils such as sponges, bryozoans and sea urchin pickles (spines?), and up to 15mm sized quartz- and lydite pebbles. Glauconite is widespread, also pyrite. The Jurassic transgression surface is hardened and encrusted or covered with *Serpulidae*. The surface is coloured green.

Interpretation:

The isopach map (Fig. 3) confirms that the Lower Greensand was deposited in a channel at Faringdon, as MELLVILLE (1937) had already concluded from his field observations. At their western edge the Sponge-Gravels reach their greatest thickness and can there be divided into the underlying Yellow and the overlying Red Gravels (MEYER 1864, MELVILLE 1937).

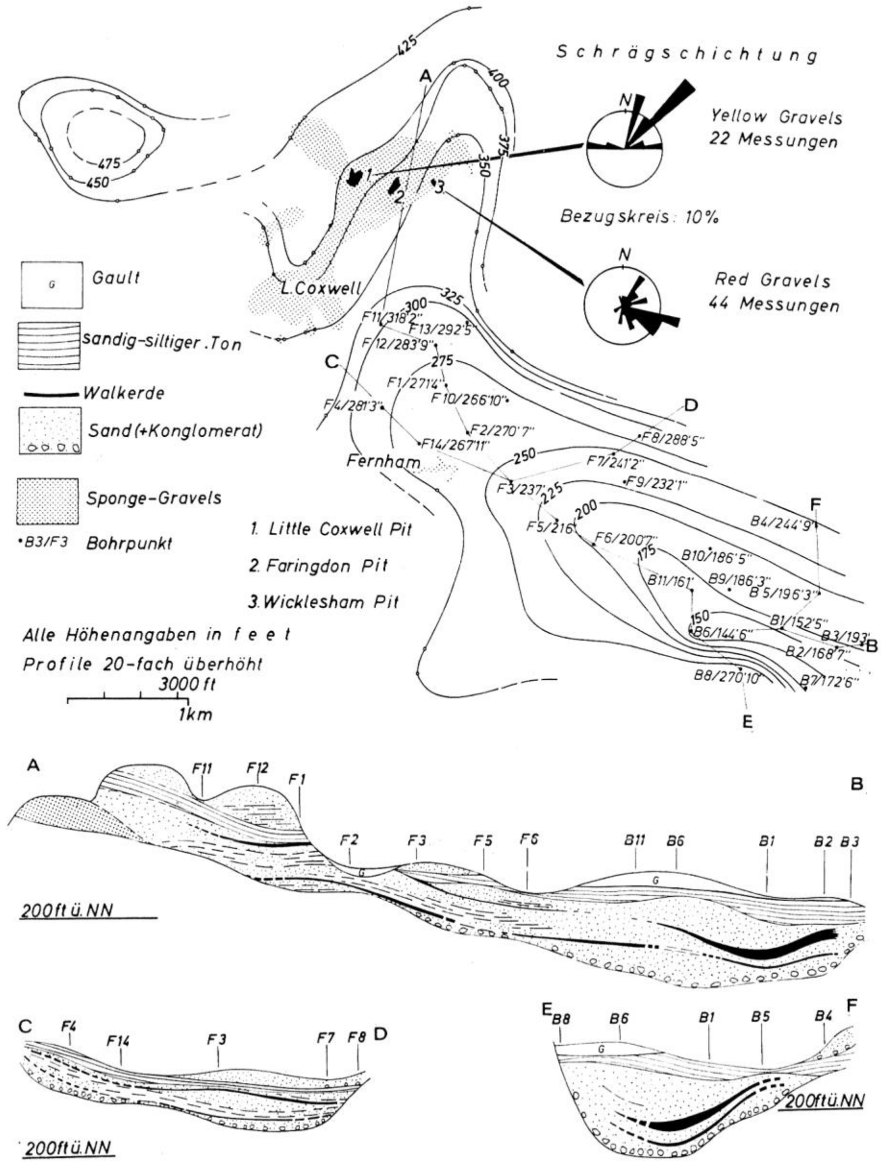

Abb. 3. Geometrie der Lower Greensand-Rinne. (Die Schichtlagerungskarte basiert auf der vom Geological Survey 1969/70 durchgeführten Kartierung im Maßstab 1:10 560 der Blätter SU 29 SE, SU 29 NE, SU 39 SW und damit verbundenen Bohrungen.)

Fig. 3. Geometry of the Lower Greensand trough. (The contour map is based on the new geological sheets [1969/70] SU 29 SE, SU 29 NE, SU 39 SW and on borings by the Geological Survey of Great Britain.)

Towards the SE, they dip under the silty sands (Fig. 2, Fig. 3), which in a borehole 400m to the south already directly overlie the Upper Corallian without a basal conglomerate (Fig. 3, profile A-B). Here, the Sponge-Gravels were later eroded in an area of more powerful current or reduced to small patches, while in the area of the "main outcrop" only the upper layers were heavily reworked.

Stratigraphy, fossil content and -conservation

Yellow Gravels

A fine to medium-grained sand with coarse bioclasts contains a rich, partly excellently preserved fauna with calcareous sponges, bryozoa, brachiopods, sea urchins and oysters (Fig. 6). A large part of the bioclastic fraction consists of bryozoic schill?, as well as plates and spines of sea urchins.

In addition, up to 10 cm long fragments of branched bryozoa and completely preserved sea urchin shells (without spines) are also present. In the sponges the good preservation of thin-walled, chambered Sphinctozoeae *Barroisia anastomosans* is particularly striking. On the other hand, bi-valved brachiopods are less common than single valves.

According to ELLIOT (1956; listing of 500 specimens), the species *Gemmarcula aurea* is found 84% fractured or single-valved. A separate count of single but unbroken valves and bivalve specimens of *Sellithyris sp.* (Count of 110 specimens) gave a similar ratio (Fig. 4).
In the case of the single valves, the pedicle valves (74%) are predominant; in the case of the arm valves the large specimens are most frequent. This distribution indicates transport separation.

The FILLING of the brachiopods consists either of strongly ferruginous sand or silt, which differs from the surrounding sediment matrix, or of fine sand matrix material.

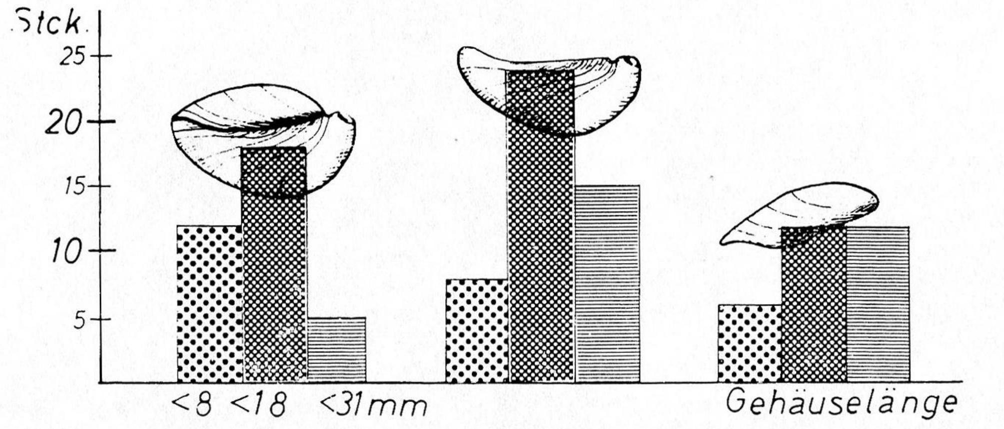

Abb. 4. Transportsonderung von Brachiopodenklappen: Stielklappen mittlerer Größe überwiegen.
Fig. 4. Selectional transport of brachiopod valves as pointed out by the preponderance of medium sized pedicle valves.

From among 37 Brachiopods, only 7 specimens remained unfilled. The gastric space of the sponges is often incompletely filled in. On the sediment-free walls as well as on flushed oyster flaps, one can see completely preserved "Epöken", e.g. finely branched Bryozoa with long out stretched Zoecien.

The lime lutite pore infill of the sponges form, if incomplete, uniformly aligned "water scales" (Fig. 5). In the case of *Raphidonema contortum* (or *R. faringdonense*), they are orientated in 67% of 86 specimens in a way analogous to the presumed living conditions (peak downwards). The sponges must therefore have stood erect for a long time after their death, so that the Lime lutum could reach the pores of the shell as a suspension and solidify in this position. The sponges came pre-fossilised into the Sponge-Gravels. In sections through hardened parts of the Yellow Gravels, it can be seen that the calcite (lime lutum) was also deposited later, for example, in the lobes of individual flaps or as a lime sludge mixed with all sorts of bioclastic material and small quartz grains. A large sponge was still enclosed in a lump of calcite (lime lutum) and quartz sand.

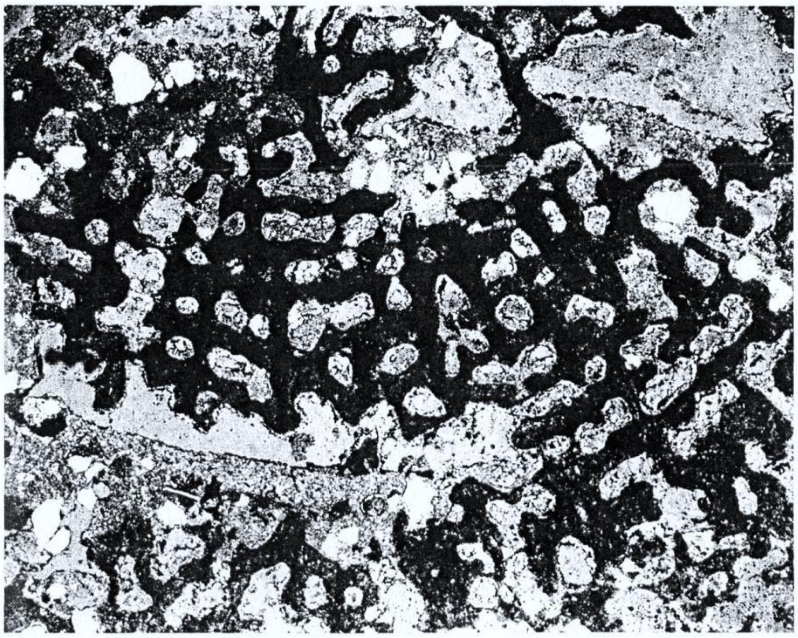

Abb. 5. Einheitlich ausgerichtete Hohlraumfüllungen in *Oculospongia* sp. (Schliffbild 20 x).
Fig. 5. Geopetal void-fillings in *Oculospongia* sp. (thin-section, 20x).

The fauna of the Sponge-Gravels is allochthonous, for the sponges, bryozoa, regular sea urchins and brachiopods are typical hard ground dwellers. Only sponges, and a part of the Brachiopods (with *allochthonous* sediment infill) are well preserved due to pre-fossilization at their origin. The delicate, branched Bryozoa had also remained pre-fossilized and still fragile. In addition, the transport behaviour differs. Pre-fossil sponges were being transported as heavy bodies rolling on the seabed, and strong currents would be necessary to transport them over longer distances. In the folds of the sponges, or in their gastric space, are found *terebratulid* brachiopods, whose hinges point to the base of the sponges.

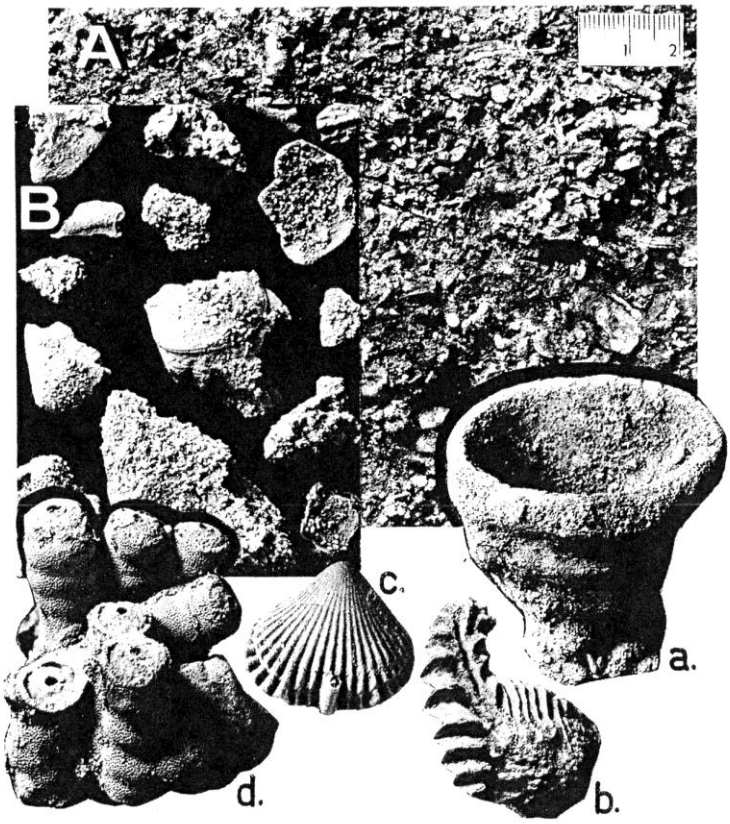

Abb. 6. Yellow Gravels: A) undeutlich gradierte Schichtung, B) kaum abgerollte Bioklastika (2 x). Vorzüglich erhaltene Fossilien: a) *Raphidonema* sp. (1x), b) *Lopha* sp. (1x), c) *Rhynchonella* sp. (2x), d) *Barroisia anastomosans* (2x).

Fig. 6. Yellow Gravels: A) indistinctly graded bedding, B) bioclasts almost not abraded (2 x). Perfectly preserved specimens of: a) *Raphidonema* sp. (1 x), b) *Lopha* sp. (1 x), c) *Rhynchonella* sp. (2 x), d) *Barroisia anastomosans* (2 x).

They only became fixed in this unstable position at a later stage. They are therefore in life position only in relation to the sponge and not to the sediment. These brachiopods are usually hollow. They were probably attached to the already dead sponge and were transported alive with it. (Since such an orientation of sponge and brachiopod often occurs, it cannot be accidental.) (See MIDDLEMISS 1962.)
This situation excludes a new re-deposition. Thus, the mentioned separation of the pedicle and arm valves (Fig. 4) is not effected by means of a rearrangement at the site but already at the time of the delivery. The biogenic portion of the sediment is thus probably *allochthonous*, but has experienced neither a long transport nor a stronger re-deposition.

This assumption can be supported by the sedimentological findings. Stratification is hardly recognizable in the fresh sediment, whereas in some cases gradational sorting is suggested (Fig. 6). A slight dip of individual bed sheets to the NE is clearly visible through the weathering. The poor sorting of the sediment (SOG = 2, 3) is mainly due to the bioclasts (SOB = 1,83, whilst the quartz sand with SOQ = 1,32 shows good grading. The maxima of the grain size distribution curves for bioclast and quartz sand fractions take different grain size ranges (Fig. 7). The broad main maximum of the quartz sand curve is in the range of fine to medium (0,125mm – 0,4mm). A secondary maximum is found in the region of 1 - 4 mm (very coarse sand / fine gravel), and there is also the broad main maximum of the bioclastic fraction, which in turn has a secondary maximum in the gravel region (> 4 mm). The curves thus show that the biogenic fraction was included in the sediment transport only shortly before the deposition. Particular hydrodynamic conditions led to a rapid deposition, as it were a "dumping" of the sediment, and largely protected it against subsequent re-deposition. A slight adjustment of both fractions is suggested by the overlap of the quartz-sand secondary maximum and main bioclast maxima (Figure 7).

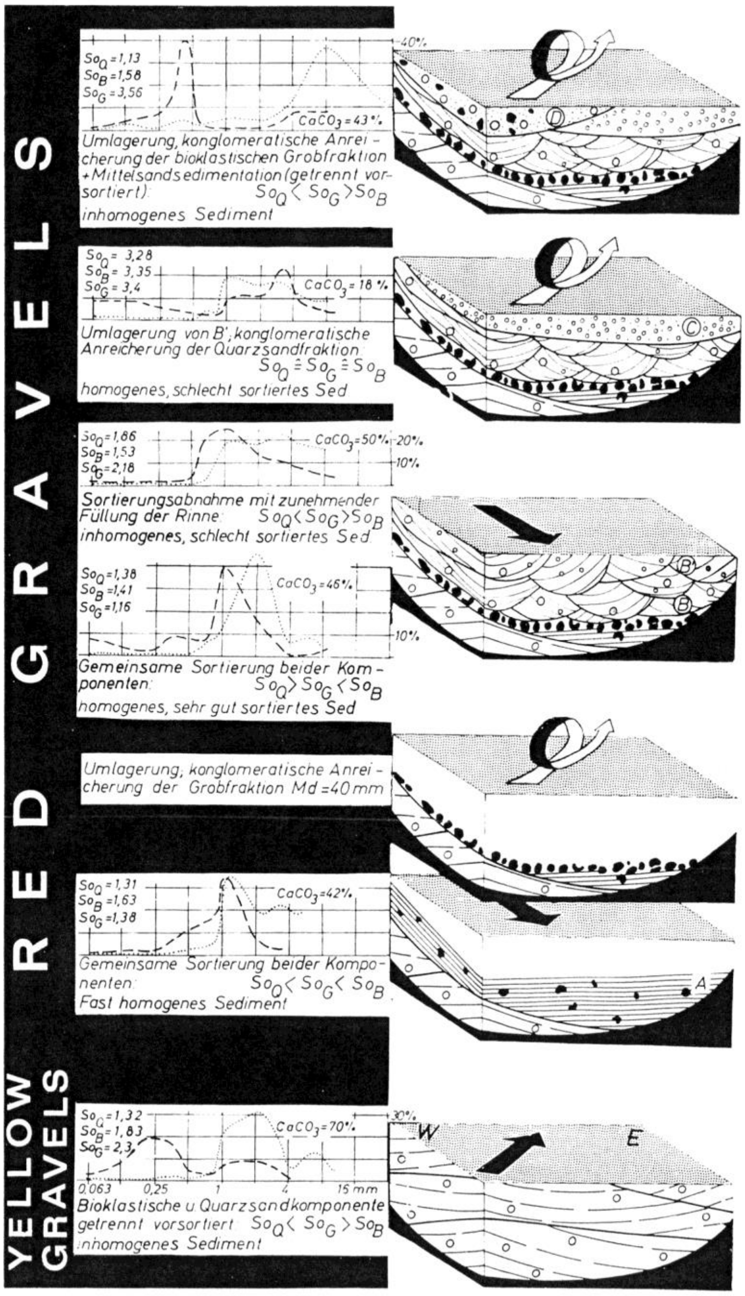

Abb. 7.

Abb.7. Korngrößenverteilung in den Sponge-Gravels und genetisches Modell. (Die Kornverteilung der bioklastischen Fraktion ergab sich durch Wägen der einzelnen Siebfraktionen vor und nach der Ätzung mit HCl. Große Sedimentpartikel, besonders ganze Schwämme blieben unberücksichtigt, da sie im Probenmaterial zu selten auftreten.) Gestrichelte Linie = Quarz-sandfraktion; punktierre Linie = Bioklastische Fraktion = $CaCO_3$; So = Sortierungsgrad nach TRASK (1932); (für Quarzsand So_Q; für Bioklastika So_B; für Gesamtsediment So_G); schwarz = jurassischer Untergrund.

Fig. 7. Grain-size distribution in the Sponge-Gravels and genetic model. (The grain-size distribution of the bioclasts ensured from weighing the single grain-size fractions before and after solution with HCl. Appearing very rarely within sampling range, large particles like sponges were not taken into consideration.) Dashed line = quartz-sand fraction; dotted line = bioclastic fraction = $CaCO_3$; So = sorting coefficient after TRASK (1932); (of quartz sand So_Q; of bioclasts So_B; of the entire sediment So_G); black = Jurassic.

Red Gravels

In the western area of the Sponge-Gravel outcrop, the Yellow Gravels are overlain by a basal conglomerate and up to 6 ft of Red Gravels (MEYER 1864, ARKELL 1947, MELVILLE 1937). Towards the NE, the Red Gravels overlap directly onto Jurassic substrate (MELVILLE, 1937; the contact now no longer exposed). In this area (Wicklesham Pit, Fig.3), the following observations are made:

The faunal population is not significantly different from the Yellow Gravels. Small, young sponges are especially numerous; Amongst the Brachiopods, the *Rhynchonellids* are more frequent than the *Terebratelin*, while they are approximately equally abundant in the Yellow Gravels.
(Subdivision fig. 2; fig. 7):

Layer A is exposed to a maximum thickness of 60 cm. It is a medium to coarse-grained quartz sand with very coarse bioclast content, which contains numerous calcareous pebbles and secondary fossils from the Jurassic substrate. Moreover, in contrast to the main mass of the Red Gravels, large sponges and sponge fragments still occur frequently in here. In the lee of the larger sediment particles, such as sponge fragments, oyster shells and limestone clusters a yellow, fine, silty sand is often concentrated. This sand also forms elongated balls of 1 to 2 cm in diameter.

They are separated from the red-coloured coarse sand matrix by a hematite coating. In the bowls of oysters and sponges, particularly coarse quartz sand grains are often enriched. Overall, the sediment is inclined; the bedding dips uniformly to the SE at approximately 12°.

Compared to the grain size distribution curve of the Yellow Gravels, the maximum of the quartz sand curve moves into the coarse to very coarse sand range (= 0.5-2.0 mm) and coincides with the maximum of the bioclast curve. In the bioclast curve, the very coarse sand component is slightly reduced compared to the now more strongly represented very fine gravel component.

The good sorting of the total sediment (SOG = 1.38: good; SOB = 1.63: mediocre) results from the improved sorting of the bioclastic fraction and the overlap of quartz sand and bioclast curves. On the other hand, the degree of grading of the quartz sand has not changed significantly (SOQ = 1.31: good) (Fig.7).

With Layer A, a higher sorting current initiated, which also persisted after the deposition and caused a reworking. This resulted in a greater destruction of the biogenic component. The resulting bioclastic fine component was washed out together with the fine quartz sand fraction, reducing the bioclastic content from 70% (Yellow Gravels) to 42%.

At the top?(*hangenden*) of layer A are bored lime- and clay pebbles, silt balls, "a spectral fauna" from the underlying Jurassic layers, as well as larger pebbles, concentrated in a conglomerate. The diameter of the pebbles and secondary fossils is between 1 and 10 cm. The conglomerate is 50 cm thick, but gets thinner towards the northwest over a distance of about 15 m and is finally only represented in the form of individual widely spread but horizon-persistent pebbles.

The secondary fossils, phosphatic cores (ARKELL 1947) of bivalved mussels and ammonite chamber fills, are mostly heavily rolled and often polished. Strong boring of the limestone pebbles indicates derivation from the coastal cliff region of the Lower Greensand Sea. The strong abrasion of the bored pebbles probably originated in the high-energy surf zone.

Abb. 8. Red Gravels, Schicht B: A) deutlich gradierte, trogförmige Schrägschichtung; B) abgerollte Bioklastika (2x).
Fig. 8. Red Gravels, bed B: A) trough cross-bedding, distinctly graded; B) abraded bioclasts (2x).

Layer B overlies the conglomerate, with its thickness (average 4 m) increasing towards the west.

The coarse-grained, very well sorted sediment contains small sponges, bryozoa and urchin spines besides the mass of abraded clasts (Fig. 8). About 40 cm above the conglomerate layer, there is locally a thin bed with pebbles. Apart from this, Layer B contains hardly any larger pebbles, secondary fossils or sand-lenses, just as little larger (>3 cm) sponges or sponge fragments.

Enrichment of coarse mostly bioclastic material, at the bottom of small troughs (width between 10 - 30 cm, height approximately 10-15 cm) emphasizes the trough cross bedding (Fig. 8, Fig.9). In Faringdon Pit, 300 m west of Wicklesham Pit, where layer B is present in a larger thickness (18ft), the channel fillings are particularly clearly graded.

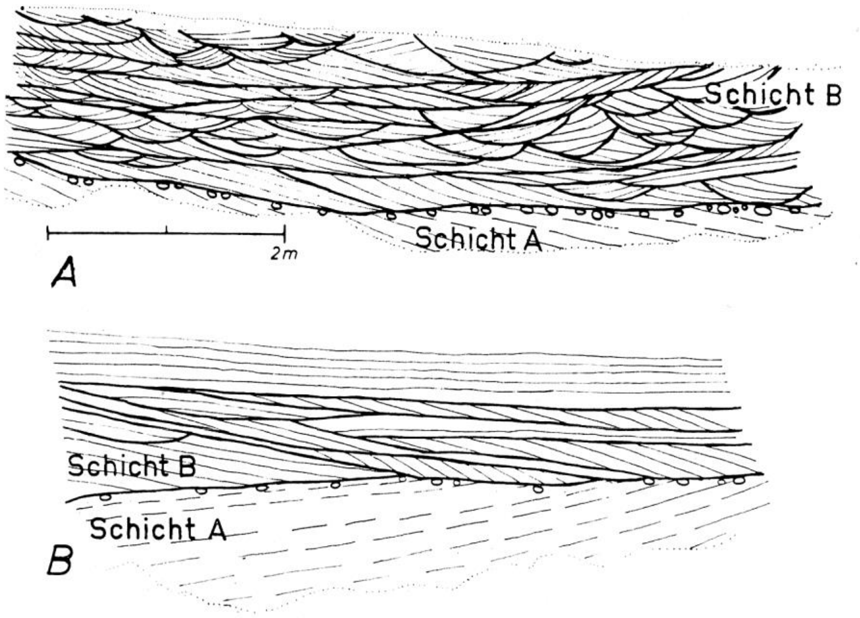

Abb. 9. Trogförmige Schrägschichtung in Schicht B der Red Gravels (Wicklesham Pit). A) Streichen der Aufschlußwand 120°, also parallel zur Strömungsrichtung. B) Streichen der Aufschlußwand 15°, also fast senkrecht zur Strömungsrichtung.

Fig. 9. Trough cross-bedding in the Red Gravels, Wicklesham Pit. A) Quarry face striking 120°, and parallel to current-direction. B) Quarry face striking 15°, and perpendicular to current-direction.

Trough-shaped cross bedding indicates higher current energy (FÜCHTBAUER 1970, p. 69). The grainsize distribution confirms this. The maximum of the quartz sand curve has not changed significantly compared to layer A; the bioclast curve has migrated back to the very large sand position; the fine components return in both curves.

The sorting of the total sediment is much better than that of the individual components at 1.16 (SOB = 1.41, SOQ = 1.38). However, it cannot be a reworked product of the Yellow Gravels, since layer B contains still excellently preserved, predominantly unfilled brachiopod shells. Though fragments in the coarser fraction (>3mm) are strongly abraded, particles from the finer fractions are sharp-edged, i.e. more in place and position than arising from reworked and abraded pre-fossilised material.

At the top?(*hangenden*) of layer B, the trough cross-bedding gradually loses itself to a nested accumulation of coarse bioclastics. A grain size analysis from this layer B' revealed very poor sorting of the total sediment (SOQ = 2.18), a moderately sorted bioclastic component (SOB = 1.53) and poor grading of the quartz sand (SOQ = 1.86). The quartz sand and bioclast curves overlap, but their maxima vary between that of pebbles to finer grain sizes (up to 0.63 mm), which are only weakly represented in the well-sorted sands of layer B. The sorting force of the current was therefore no longer sufficient to wash out relatively fine components (i.e. <1 mm).

Layer C, with sharp boundaries, consists of medium-grain quartz sand partly cemented with hematite, which contains numerous small pebbles and few brittle and detached, poorly distinguishable bioclastics. Horizontal stratification or bedding is recognisable only from a certain distance; also the sediment is not graded.

The sorting of the total sediment and of the individual components is VERY POOR (SOG = 3.4, SOB = 3.35, SOQ = 3.28). Fine pebbles (= 3mm), but also fine sand (= 0.3mm) are clearly visible in the quartz sand curve. Contrasting with Layer B', the coarse component (=3mm) in the bioclast curve is more weakly represented (Fig. 7).

Obviously, even before the deposition of layer C, the delivery of fresh, biogenic material came completely to a standstill. The sediment originates instead from the reworking of existing layers (especially layer B'). In this case, the quartz sand fraction results in a slight coarsening, while the bioclastic fraction reduces to 18% by destruction of coarser and leaching of finer particles. The increased fine sand content (in the quartz sand fraction) was probably delivered additionally.

Layer D, cutting as a channel into layer C (diameter of the channel about 15m) is a medium-grained quartz sand with coarse, strongly abraded sponge fragments and calcareous pebbles. Smaller fossils such as Brachiopods and Bryozoa are absent. Vertebrate teeth, bones, and wood, which only occur individually in the underlying layers, are most common in layer D. The sediment is mostly calcite cemented. Due to weathering, the impression occurs of a streaky horizontal layering. In the unstable sediment, only a horizontal orientation of the flat pebbles can be seen (Fig.10).

Compared to all other grain mixtures of the Red Gravels, layer D shows a clear fining of the quartz sand fraction with a narrow maximum at
0.4 mm, and a coarsening of the bioclastic fraction with a broad maximum between 4 and 20 mm. Accordingly, the SORTING of the total sediment is VERY POOR (SOG = 3.56) (Fig. 7).

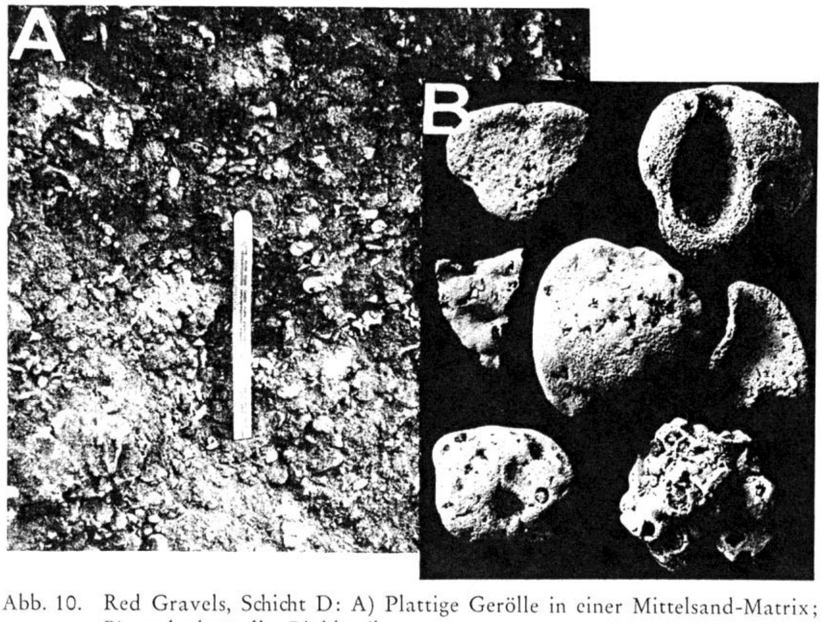

Abb. 10. Red Gravels, Schicht D: A) Plattige Gerölle in einer Mittelsand-Matrix; B) stark abgerollte Bioklastika (1x).
Fig. 10. Red Gravels, bed D: A) flat pebbles in medium-grained quartzsand; B) heavily abraded bioclasts (1x).

The coarsening of the bioclastic portion is due to the extremely STRONG REWORKING of the old Sponge-Gravel material. Thereby the finer material (brachiopod shells and bryozoa branches) became completely ground up and washed out. Only the very coarse particles, such as sponges and limestone gravel, (which, because of their relatively sporadic distribution, did not enter into the sampling of the other layers) are enriched. The well-sorted, fine quartz sand (SOQ = 1.13), however, comes from a NEW SEDIMENT SUPPLY. During its deposition, the concentrated bioclastic fragments were stirred up, resulting in a mixing of the two components. On the other hand, the coarse biogenic fragments could have been transported, with the fine quartz sand fraction, shortly before deposition in a channel, similarly to the deposition of the yellow gravels.

Interpretation:

With increasing filling of the channel, reworking is increasingly dominant to fresh sediment feed. Accordingly, the biogenic portion of the sediment becomes ever smaller and the preservation of the hard parts becomes ever worse. A concentrate is present at the end in which calcareous (*corallian*) and rolled sponge fragments are secondary enriched as the largest and most resistant sedimentary particles. The inverse gradation is therefore primarily due to the increasing processing of sediments and at the same time of decreasing sediment supply.

The following stages can be deduced for the sedimentary process (Fig.7):

1. Local subsidies of biogenous coarse debris to quartz sand, which has already been transported for a long time, resulted in inhomogeneous sediment that was fixed as Yellow Gravels by subsequent deposition. Cross bedding indicates a filling from the SW, i. e. inclined to the channel axis and landwards. It is conceivable that an extensively current was weakened when crossing the NNE-SSW channel, so that the coarser Sediment together with uninjured organism residues was trapped (Fig. 3).

2. In the Red Gravels, Layer A represents a period of severe erosion and a contrary, i.e. from the coast originated sediment transport. Due to subsequent enrichment of the coarse fraction, it was largely transformed into a basal conglomerate. Only in a protected layer at the bottom of the channel, layer A was retained under a slight conglomerate layer.

3. Due to lateral accumulation of the Yellow and the Red Gravels, the channel centre had increasingly shifted in direction to the East. Layer B lies directly in the E on the Jurassic channel floor and only reaches the marginal Yellow Gravels in the course of increasing filling. The homogenisation of the bioclast and quartz sand fraction in layer B is less attributable to changed current conditions than to a long-term rearrangement of the sediment of the channel at a continuous supply of material. The sorting effect of the current also decreases with increasing filling of the channel (layer B ').

4. Subsequent reprocessing of layer B 'reduces the percentage of bioclast material due to abrasion to 18% (layer C).

5. A new channel is cut into the old fill. Enrichment of coarse sediment particles leads to the formation of a sponge concentrate with a medium-grain quartz sand matrix (layer D).

Fauna and Ecology

Characteristic of the Sponge-Gravels are the lime sponges and cyclostomen Bryozoa, associated with brachiopods, oysters and regular sea urchins, i.e. predominantly hard ground residents.
In the SPONGES (HINDE 1883), the inarticulate INOZOA, with 15 species, predominated against 2 species of the Sphinctozoa. In contrast to the Sphinctozoa, they have great variation possibilities. Due to the often extremely severe folding of the housing, as well as to the formation of pustules and wrinkles, they reach a surface enlargement, which also enables them to reach an optimal nutritional intake in a limited space. In addition, a strongly deflected cup is much more stable than an unfolded cup of the same surface area. In the case of the Barroisia, the only representatives of the SPHINCTOZOA, the support function is solely due to the ectosome (SEILACHER, 1961). The sponges are partly grown together with each other, whereby a separating layer or cortex is often not developed, so that allegedly different types and generations are grown together.

According to ZIEGLER (1965), this is an indication of an extraordinary variability caused by different current- and light conditions, and probably at the same time due to the high settlement density observed in living species (DE LAUBENFELS 1957).

As already mentioned, the sponges contain suspended water scales (spirit levels?)(Fig. 5, Fig. 11). They correspond to the assumed living position for *Raphidonema* in 67% of 86 species, although it is the most unstable position.

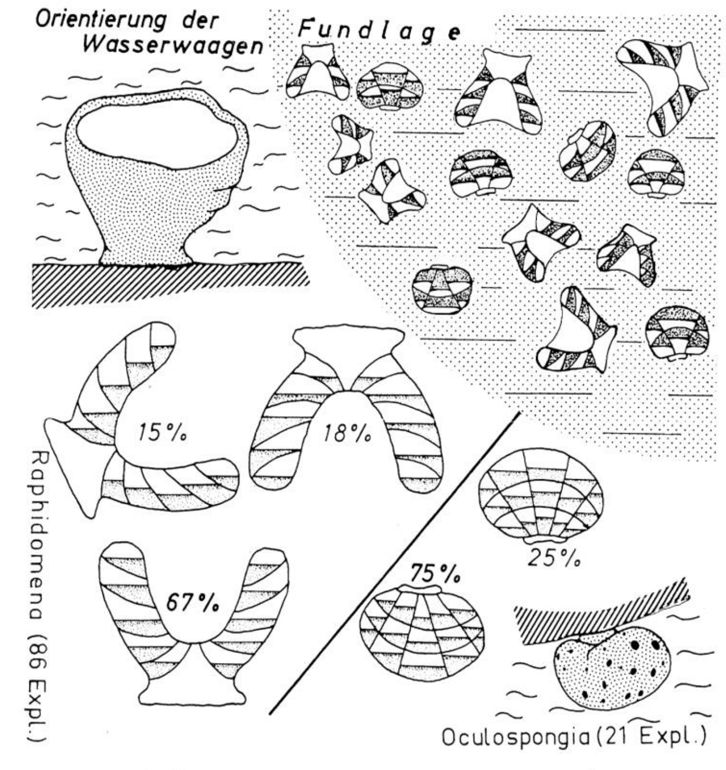

Abb. 11. Präfossile Wasserwaagen erlauben die einstige Lebendstellung auch aus umgelagertem Material abzuleiten, besonders, wenn sie nicht mit einer stabilen Einbettungslage zusammenfällt.
Fig. 11. According to prefossilized void-fillings a former growth-position can be reconstructed, especially if it does not coincide with a stable position.

Therefore, the orientation of the water scales can also be assigned to other forms of living position. In the case of the small, spherical *oculospongia,* it occurred that it was attached with the base to the top, that is to say, hanging (Fig. 11). This is supported by an observation

by ZIEGLER (oral communication), which also found the small, spherical *stellispongia* attached to the underside of coral stems.
On the seafloor, such small-scale forms would probably have been overgrown too easily, or were covered by sediment. The subordinate orientation (Fig. 11) can also be attributed to deviant living positions, at least in lateral position, as they developed in reliefs, mutual impediment or uprooting.

RECENT PHARETRONOAE are tied to largely constant temperatures and low light exposure. They therefore live preferably in underwater caverns at a temperature of around 20°C. VACELET (1970) interprets this way of life as a retreat of a remnant fauna, which, at its height, occupied wide spaces in larger, i.e., low-light depths of warm seas. Only the Minchinellids have definite fossil representatives. The relationship is uncertain between the fossil pharetronida and the recent Lelapiidea (DE LAUBENFELS, 1957), which only secrete needle bundles without a solid lime skeleton and are the only ones of the recent pharetronoae in the light flooded shallow sea.

In any case, the pharetronoae were not photophobic, as shown by their frequent occurrence in the triassic diplopore limestone DIPLOPORENKALKEN??? (OTT 1967) and in Upper Jurassic coral reefs (WAGNER, 1964).

In the BRYOZOA (CANU & BASSLER 1926) both encrusting (21 species) and free growing (33 species) are to be distinguished. The latter form either finely branched bushes (18 species) or thick-bodied, slightly branched individual sticks (15 species) and nodules. According to live observations by SCHOPF 1969, the finely branched forms off the coast of New England only occur from a depth of 35 m. WAAS et.al. (1970) found them at the Australian South coast only at a depth of 50-120 fathoms (= 100-240m). So there are probably very local conditions that determine the depth distribution. The occurrence of the different forms of bryozoa is probably primarily dependent on the turbulence or the velocity of the current, the substrate and the sedimentation rate (SCHOPF 1969). The free-growing forms described from the Sponge-Gravels prefer hard grounds by analogy with living observations by SCHOPF (1969). They tolerate current velocities of up to 100 cm / sec and a low sedimentation rate (0-10cm / 10^3). They probably grew in lawns??? or in the lee of the current of large sponges.

The BRACHIOPODS (DAVIDSON 1852, 1854, 1973, MIDDLEMISS 1959) are represented with 17 species. Some of them are quite peculiar in their GROWTH HABITS: at medium size of *Sellithyris coxwellensis* the strips grow ever closer together, resulting in a steep, front surface (MIDDLEMISS 1959). Symmetry deviations and irregular shell bulges and indentations are also very frequent. The recent *Terebratula obselata*, which lives in turbulent shallow marine environments, exhibits similar irregularities (DUBOIS 1916).

The strongly developed spine region and the large foramen to a strong stem of the Sponge-Gravel brachiopods, can be seen as an adaptation to higher water turbulence (ELLIOT 1947). Some brachiopods have been bored by predators, most often at the upper part of the stalk valve. Nevertheless, they often remained two-valved.

In the case of the SEA URCHINS (WRIGHT 1864-1882), the small-growing genera *Salenia* and *Hyposalenia* are mainly completely preserved, while the isolated plates and spines in the bioclastic fraction originate predominantly from *Cidaris*. In addition to the REGULAR (8 species), the Red Gravels rarely carry irregular, burrowing sea urchins (2 species of the genus *Trematopygus*).

The *LAMELLIBRANCHIATES* -Fauna (WOODS 1899-1912) are, apart from the oysters, rich in species (21 species) but poor in individuals. Out of 21 species, only Astarte *elongata* and *Trigonia* sp. (Only 2 findings) are *endobenthontic*. The only gastropod shell ever described from the Sponge-Gravels is probably attributable to the genus *Trochus*.

Encrusters on the sponges, brachiopods and oysters are recruited from various animal groups. Among them the Bryozoans with 19 species are predominant, besides which are quite large serpulids (especially *glomerula*), oysters and thecids. Neither Bryozoa nor serpulides have grown orientated. The encrusting Bryozoa (e.g., *Berenicea*) are often grown on sponges as well as on Brachiopods and on oyster shells; branched creeping? colonies (i.e. *Probiscina*) prefer the smooth inner surfaces of Oysters and Brachiopods. Spherical Bryozoa (i.e. *Multigalea*) often attach to the upper edge of the sponges.

In contrast, in the case of Thecideen, which grow in groups on funnelled sponges, the whorls? are usually oriented towards the base of the sponge, that is in the living position of the host, slope orientated.

A general interpretation of the whole growth as pre-or postmortal, however, cannot be derived from this. Only in individual cases Epöken had been overgrown by the sponge, or had prevented their growth (premortally), or had overgrown the fracture or base surfaces of the sponge themselves (postmortally).

The question of whether postmortal growth occurred at the site of life or at the site of deposition is even more difficult to answer. For most of the organisms (sponges, free-bryozoans, brachiopods, oysters or regular sea urchins) occurring in the Sponge-Gravels, the loose sand was probably unsuitable as a habitat. Only epizoic bryozoans and serpulides could also find a suitable substrate here on sponges, brachiopods, etc. Such autochthonous growth is demonstrated by:

a *Berenice*a from the Red Gravels, which has also overgrown quartz particles on the sponge base, (…)

a Serpulid from the Red Gravels, which –grown on a sponge- incorporates a pebble

According to SCHOPF (1969), a frequent incidence of encrusting bryozoa suggests a low sedimentation rate (10cm / thousand years). But the enumerated uniquely autochthonous growth forms are individual cases and cannot be generalized just like that.

It is probable that the majority of the species of organisms found in Faringdon belong to one and the same faunal community, because they consistently comprise hard-ground residents of well-aerated and calm shallow marine conditions.

According to MIDDLEMISS (1963) the coast was not more than three miles away during the deposition of the Sponge-Gravels. On the assumption that brachiopod preservation deteriorates with increasing distance from the coast, he distinguishes three zones in the

Bargate Beds. Correspondingly, the contemporary Sponge-Gravels would be assigned to the near coastal zone where the distance from the growth location was no more than a mile.

Interpretation:

1. The fauna of the Sponge-Gravels are derived from the dense growth of neighbouring cliffs of Corallian limestone. ???

2. Strong currents transported loosened sponges, bryozoa etc. together with already rolled and pre-sorted shell material.

3. With the onset of sediment-laden currents coming from the onshore, the living conditions deteriorated for the inhabitants of the hard ground. The supply of fresh fossil sands therefore sharply decreases in the Red Gravels. At the same time single digging forms appear (mussels, irregular sea urchins, MELVILLE, 1937).

4. Palaogeographically the Sponge-Gravels can be compared with a Fore-Reef-deposit (MIDDLEMISS, 1963).

Sedimentological association (Fig. 2)

It has been shown that the sedimentation of the Sponge-Gravels gradually decays over a period of re-working and a change in the current direction. This also corresponds to the sedimentation of finer quartz sand between the gravels of layer D (Fig. 7, Fig. 10). The subsequent clay sands and laminated clays (Fig. 2) finally indicate the complete filling of the trough (Fig. 3, profiles).

The clay sands are characterised by the frequent occurrence clay pebbles and especially by synsedimentary slipped slabs, which lie at an angle of up to 40°C to the layered sequence. Both phenomena are observed in recent settings especially in the *Watt*, and can be traced back to a strong deposition of the sediment (SCHWAR 1979, REINECK 1971). Strong bioturbation and frequent occurrence of plant remains can also be attributed to a *watt*-like environment in this context.

The origin of the two Fullers Earth horizons (was attributed by POOLE & KELK (1971) on the precipitation of *Ca-montmorillonite* from river water into the marine (i.e. alkaline) environment, preferably in a particularly protected position; It is conceivable that especially the southern W-E running part of the Lower Greensand channel at Faringdon was temporarily cut off from coarser sediment supply, and therefore the deposit of the very thick and pure Fullers horizons (Fig.3) could develop.

The final stage of the channel filling is reached by deposition of the laminated clays (Fig. 2, Fig. 3). Their mostly planar fine-layering points to a higher current velocity, as does the reduction of bioturbation, while the fairly regular alternation of sand and clay indicates periodically fluctuating water movement.

The predominant feature of the iron-rich sands, which were deposited after completion of the channel filling (Fig. 3), is a rapid change in the grain size distribution. Both the lensing and crossbedding, as well as the occurrence of wood and carbonaceous material indicate deposition near the beach. Even wind transport was effective, because in the area of convex crossbedding, which is regarded as a feature of Aeolian deposits (MACKENZIE in LAND 1967) sand grains are particularly frequently layered in the grain size ranges between 0.25 mm and 0.63 mm .

Interpretation:

The Lower Greensand of Faringdon represents altogether a regressive sequence. Compared to the Lower Greensand occurrences of the Weald region, the regression here began very early: the iron-rich sands are a diachronous facies and correspond stratigraphically to the Sandgate Beds, but their facies correspond to the upper Folkeston*e* Beds (POOLE & KELK 1971).

Diagenetic processes

Even before deposition of the Sponge-Gravels, the first stage of diagenesis begins with the early consolidation of the lutite filling in the sponges. In the pores of the sponge skeleton, the local super saturation with $CaCO_3$ and an increase in the pH value due to degradation of organic material, led to early emplacement of the lutite. ZORN (1969) has attributed the early consolidation of comparable lutite fillings to the activity of algae, which were stuck to the roof of the cavities in sediment particles.

This resulted in a "Geofugal Structure". Such an interpretation is rejected for the present case, since the fillings are partly graded and the calc-lutite is located in the chambers of individual brachiopod valves in the same *geopetal* manner.

In a later early diagenetic stage, calcite was precipitated in the form of thin crystallised skins around the organic hard parts, and sometime later also hematite was precipitated amorphously or in idiomorphous crystals. Finally, cementation followed with calcite spar.

While the fossils situated in the upper? (hangende) sands ……? solution or silicification, unless the early calcite cementation prevented them, the fossils in the loose Sponge-Gravels are scarcely corroded and show only slight signs of recrystallization. The exceptions are Aragonite shells (mussels and especially snails), which one would have expected in the fauna of near-coastal hard ground. They are represented in the Sponge-Gravels only by thin calcite layers of shells or rarely by sandy internal casts.

Of the large Nautilus shells of the Red Gravels, only the lower half is preserved, and also here the actual shell is removed and replaced by a calcite skin, which wedges from the middle of the lying surface to the sides, and only slightly causes a fusion on the edge of the sand grains. In the weakly cemented internal cast, brachiopods are often found in a nest-like concentration.

The differing colouring of the Sponge-Gravels is due to a changing hematite content: Yellow Gravels: Fe_2O_3 = 3.38% MnO = 0.05% Red Gravels: Fe_2O_3 = 8.75% MnO = 0.10% (Quantitative Analysis: Geochemical Central Laboratory, Tübingen).

Since these iron enrichments are mainly due to products of continental weathering (FÜCHTBAUER, 1970, p. 524), it is conceivable that the Sponge-Gravels, soon after their deposition, came into the influence of fresh water: as a porous layer between clays and limestones in the underlying Clay (Kimmeridge Clay, Corallian) and overlying fine sands and clays (Lower Greensand) (Fig.2; Fig. 3), they could have formed the continuation of a continental body of groundwater, and with the small difference in density between fresh and salt water, a slight pressure head was enough for displacement of the salt water contained in the Sponge-Gravel.

If one assumes on the one hand that this ground water was supersaturated on $CaCO_3$, but on the other hand it contained large amounts of CO_2, it becomes clear that on the one hand no CaCO3 was dissolved, and on the other hand a cementation of the Sponge-Gravels by precipitation of $CaCO_3$ was avoided. As a function of the porosity, iron was preferably deposited/separated in the well-sorted, coarse Red Gravels, but less in the poorly-sorted Yellow Gravels with finer quartz sand.

Interpretation:

The excellent preservation of the calcite shell material in the loose quartz sand was probably made possible by the "diagenetic replacement" of the Aragonite shell material, whereby non-marine groundwater could have prevented the cementation.

Paleogeographical Contexts

At the beginning of the Upper Aptian, the sedimentation of the Lower Greensand was interrupted by a phase of tectonic movement and subsequent erosion, which led to the NUTFIELDENSIS-transgression: like a swamping? (CASEY 1961), the sea penetrated from the WEALD area towards the W onto a Jurassic substrate. There the "WESTERN OUTLIERS" (KIRKALDY 1939, CASEY 1961) (Fig. 1) developed, a series of isolated occurrences of largely reduced thicknesses of iron-rich sand. Where, as in Faringdon, they attain greater thicknesses, there is also a rich, peculiar fauna, limited to the basal strata. Regardless of the question whether the increase in the thickness was due to tectonic action (MELVILLE 1937) or caused by an erosive relief (KIRKALDY 1939, ARCELL 1947, CASEY 1961), most of the authors agree that the "WESTERN OUTLIERS" were already originally deposited in separate embayments, and thus reflect a shallow marine environment.

This is true for the Sponge-Gravels as well as for the fossil deposit at *Seend* (Fig. 1), where amongst a fauna of brachiopods, lamellibranchs and gastropods, limpets (*Napfschnecken*) are particularly typical. The Lower Greensand deposits of the European mainland can also partly be included in this framework. BARROIS (1878) described a channel fill from the Ardennes (Blangy), where the Lower Greensand in the Aptian transgressed over crystalline Palaeozoic, at the base of which sponges and brachiopods lie abundantly in a clayey matrix. BARROIS (1878) found close faunistic relationships to the Sponge-Gravels of Faringdon.

Interpretation: As in Faringdon, the same fossil deposits are found at the base of small, isolated deposits in a near-coast environment.

Acknowledgments:

D a n k :

Die Bearbeitung der Sponge-Gravels wurde von Herrn Dr. R. GOLDRING, Reading angeregt und im Rahmen des Forschungsprogramms „Fossil-Lagerstätten" durchgeführt.

Für ihr stetes Interesse und zahlreiche Anregungen danke ich vor allem den Herren Prof. Dr. A. SEILACHER und Prof. Dr. F. WESTPHAL, Tübingen. Herrn Dr. R. GOLDRING bin ich für die Einführung im Gelände dankbar. Dem Sedimentology Research Laboratory und seinem Direktor Herrn Prof. Dr. J. R. ALLEN, Reading verdanke ich Unterlagen für die Geländearbeit. Herrn Prof. Dr. B. ZIEGLER, Stuttgart und Herrn Prof. Dr. K. CHAVE, University of Hawaii danke ich für die Diskussion spezieller Fragen der Ökologie und Diagenese.

Ganz besonderen Dank schulde ich dem Geological Survey of Great Britain und seinen Mitarbeitern, den Herren Dr. B. KELK, E. POOLE und Dr. R. MELVILLE für großzügige Informationen im Rahmen der Geländearbeiten und wertvollen Rat in allen strittigen Fragen.

Weitere Anregungen ergaben sich auch aus der Diskussion mit Tübinger Kollegen und Teilnehmern des Rundgesprächs „Fossil-Lagerstätten".

Finanzielle Unterstützung verdanke ich der Deutschen Forschungsgemeinschaft.

Das Material zu dieser Arbeit (Kat.-Nr. 1428) befindet sich im Geol.-Paläont. Institut der Universität Tübingen.

Bei A. SEILACHER eingegangen am 19. September 1971.

A n s c h r i f t d e r V e r f a s s e r i n :

RENATE KRANTZ, Institut für Geologie und Paläontologie, 74 Tübingen, Sigwartstraße 10.

References:

Literatur

ARKELL, W. J.: The Geology of Oxford. — Clarendon Press, Oxford 1947.

AUSTEN, R. A. C.: On the age and position of the fossiliferous sands and gravels of Faringdon. — Quart. J. Geol. Soc., **6**, 454—478, London 1850.

BARROIS, C.: Mémoire sur le terrain Crétacé des Ardennes et des régions voisines. — Ann. Soc. Géol. Nord, **5**, 227—487, Lille 1878.

CANU, F. & BASSLER, R. S.: Studies on the cyclostomatous bryozoa. — Proc. U.S. Nat. Mus., **67**, 1—124, Washington 1926.

CASEY, R.: The stratigraphical paleontology of the Lower Greensand. — Paleont., **3**, 487—621, London 1961.

DAVIDSON, T.: A Monograph of the British fossil Brachiopoda. — Paleont. Soc., **6**, **8**, **27**, London 1852, 1854, 1873.

ELLIOT, G. F.: The development of a British Aptian brachiopod. — Proc. geol. Assoc., **58**, 144—159, Colchester 1947.

FRY, W. G.: The biology of the porifera. — Symp. Zool. Soc., **25**, London 1970.

FÜCHTBAUER, H. & MÜLLER, G.: Sedimente und Sedimentgesteine. — Schweizerbart'sche Verlagsbuchhandlung, Stuttgart 1970.

HINDE, G. J.: Catalogue of the fossil sponges in the British Museum (Natural History), London 1883.

KEEPING, W.: The fossils of Upware and Brickhill. — Sedgwick Prize Essay for 1879, Cambridge 1883.

KIRKALDY, J. F.: The history of the Lower Cretaceous period in England. — Proc. Geol. Assoc., **50**, 379—416, London 1939.

LAND, L. S.; MACKENZIE, F. T. & GOULD, S. J.: Pleistocene history of Bermuda. — Bull. Geol. Soc. Amer., **78**, 993—1006, Boulder 1967.

LARSEN, G. & CHILINGAR, G. V.: Diagenesis in sediments. — Dev. in Sedimentology, **8**, Elsevier, Amsterdam 1967.

LAUBENFELS, M. W. DE: Marine sponges. — Treatise on marine ecology and paleoecology, **1**. — Mem. geol. Soc. Amer. **67**, 1083—1087, New York 1957.

— Sponges of the post-paleozoic. — Treatise on marine ecology and paleoecology, **2**. — Mem. geol. Soc. Amer., **67**, 771—773, New York 1957.

LHUYD, E.: Lithophylacii Britannici Ichnographia. 2. Ausg. London 1760.

MANTELL, G.: The wonders of Geology. — 2 Bd., 3. Ausg. London 1838.

— The medals of creation. — 2 Bd., 3. Ausg. London 1844.

MELVILLE, R. V.: The Lower Greensand of Faringdon. — Unveröff. Arbeit, Reading 1943.

MEYER, C. J. A.: Three days at Faringdon. — Geologist (Geol. Mag.), **7**, 5—11, London 1864.

MIDDLEMISS, F. A.: English Aptian Terebratulidea. — Palaeont., **2**, 94—142, London 1959.

— Brachiopod ecology and Lower Greensand paleontology. — Palaeont., **5**, 253—267, London 1962.

OTT, E: Segmentierte Kalkschwämme (Sphinctozoa) aus der alpinen Mitteltrias und ihre Bedeutung als Riff-Bildner im Wettersteinkalk. — Bayer. Akad. Wiss., Math. nat. Kl. Abh. N. F., **131**, 1—96, München 1967.

POOLE, E. G. & KELK, B.: Calcium montmorillonite (fuller's earth) in the Lower Greensand of the Baulking area, Berkshire. — Rep. No. 71/4, Inst. geol. Sci., London 1971.

— The occurrence of fuller's earth (Calcium montmorillonite) deposits in the Lower Greensand of the Fernham area, near Faringdon, Berkshire. — ibid. im Druck.

REID, R. E. H.: Bathymetric distributions of Calcarea and Hexactinellida in the present and the past. — Geol. Mag., **105**, 546—559, Hertford 1968.

REINECK, H. E.: Sedimentgefüge im Bereich der südlichen Nordsee. — Abh. senckenb. naturforsch. Ges., **505**, 1—138, Frankfurt a. M. 1963.

SCHOPF, T. J. N.: Paleoecology of ectoprocts (bryozoans). — J. Paleont., **43**, 234—244, Tulsa 1969.

SEILACHER, A.: Die Spinctozoa, eine Gruppe fossiler Kalkschwämme. — Akad. Wiss. Lit., Abh. math. nat. Kl., 720—790, Mainz 1962.

SHARPE, D.: On the age of the fossiliferous sands and gravels of Faringdon and its neigbourhood. — Quart. J. Geol. Soc., **10**, 176—198, London 1854.

TRASK, P. D.: Origin and environment of source sediments of petroleum. — Houston Gulf Publ. Co., 67 ff. 1932.

VACELET, J.: Interprétation nouvelle de la fibre des éponges pharétronides (Calcispongia) fossiles d'après les pharétronides actuelles. — N. Jb. Geol. Paläont. Mh., **10**, 433—439, Stuttgart 1960.

WAGNER, W.: Kalkschwämme aus dem Korallenkalk des oberen Malm von Laisacker bei Neuburg a. d. Donau. — Mitt. Bayr. Staatssamm., **4**, 23—26, München 1964.

WAAS, R. E.; CONOLLY, J. R. & MACINTYRE, R. J.: Bryozoan carbonate sand continuous along southern Australia. — Mar. Geol., **9**, 63—73, Elsevier, Amsterdam 1970.

WOODS, H.: British Cretaceous Lamellibranchia. — Paleont. Soc., **53—76**, London 1899—1912.

WRIGHT, T.: British Cretaceous Echinodermata. — Paleont. Soc., **18—36**, London 1864—1882.

ZIEGLER, B.: Bewuchs auf Spongien. — Paläont. Z., **38**, 88—97, Stuttgart 1964.

— Die Cortex der fossilen Pharetronen. — Ecl. geol. Helv., **57**, 803—822, Basel 1964.

— Die Variabilität bei Pharetronen. — Paläont. Z., **39**, 106—110, Stuttgart 1965.

ZORN, H.: Frühdiagenetische Vorgänge im Salvatore-Dolomit (Mitteltrias, Kanton Tessin, Schweiz). — Z. dt. geol. Ges., **121**, 163—177, Hannover 1970.